

CRITICAL SITUATIONS IN THE MINERAL METABOLISM OF HUMAN BEINGS AND DOMESTIC ANIMALS

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As I think of animal life, metabolism is one indivisible system—mineral metabolism existing only as we choose to concentrate our attention on the mineral elements which are involved in all metabolism; but, for convenience sake, I concede the conventional point-of-view, and have chosen to discuss those conditions relating to mineral metabolism of man and domestic animals which frequently intrude themselves upon our attention.

Since I happen to have grown up in the family of a zoologist it is my habit to think of the nutritive requirements of man and his animals as having been determined primarily during the evolution of the species, and only secondarily as modified since the dawn of civilization.

The fundamental situation with which we have to do, therefore, is the natural harmony between the animal and its environment—the adjustment between metabolism, structure, nutritive requirements and food supply—which arose by processes of evolution, and was maintained by natural selection, before the development of the human mind brought a new and profoundly disturbing element into the situation.

Incidentally, this was only yesterday, in the history of the species.

What, then, has happened—what has mankind done—to disturb this ancient harmony, and to bring upon us critical situations with reference to mineral nutrition?

These disharmonies in the nutritional affairs of human beings began with the use of fire in the preparation of food—with resulting injury to the vitamins, which, either directly or indirectly, influence mineral metabolism. This applies, especially, to vitamins A and C, which are readily damaged by heat and oxygen; vitamin B, which is sensitive to heat and moisture, and vitamin G, which is destroyed by dry heat.

Also cooking renders food pasty, so that it sticks to the teeth, and undergoes acid fermentation.

Furthermore, the cooking of food greatly diminishes the need for use of the teeth; and thus tends to diminish the circulation of blood to the jaws and teeth, and to produce underdevelopment of the maxillary and contiguous bones—thus leading to contracted dental arches, and to malocclusion and impaction of the teeth, with complications of great seriousness.

The second outstanding incident among the nutritional adventures of mankind was his adoption of agriculture as a method of living—especially because it led to a diet based upon cereal seeds and seed products, with large use of sugar. In the manner in which we use cereal foods they tend toward deficiency of virtually all nutrients that are ever lacking in the human diet except energy-producing nutriment, and vitamin E—which controls reproduction.

A third incident of significance in relation to mineral metabolism of human beings—the taking up of residence in houses, with roofs over them, and with glass windows, has added further to one of our nutritional difficulties by diminishing our contact with the short, chemically potent, ultra-violet light waves, which transform the ergosterol of the skin into vitamin D—thus endowing it with power to catalyze the most efficient utilization of calcium and phosphorus.

It is true that agriculture has also increased the available supplies of those classes of foods which are nutritionally better balanced than are refined cereal products—namely, meat, milk, fruits and vegetables—but out of the situation as a whole has come a new freedom to use nutritively deficient foods, of which we have availed ourselves, and an obligation to balance our diet, by the use of other kinds of foods, which we have not had the wisdom and the will to satisfy.

The fault is not with agriculture, but with humanity.

Manufacture, transportation, and commerce have also contributed to this new freedom and new responsibility in food selection; soil exhaustion has served to diminish the content—in some foodstuffs—of some mineral nutrients, especially iodine; and cultivated tastes dictate that we throw away valuable mineral nutrients in the skins of vegetables, in the skins and cores of fruits, in the less palatable parts of cereals, and in discarded cooking water.

Coincident with these changed conditions of diet and habitation have arisen certain minor changes in mankind himself—through diminished severity of natural selection, and

the substitution therefor of selection on bases of indifferent or of definitely disgenic effect.

This cessation or diminished severity of natural selection applies in a general way, as life has become easier, but is especially significant in relation to mineral metabolism in connection with the teeth, with fat digestion by infants, and with the function of lactation.

Thus, before the days of cooking and milling, the teeth of mankind had a definite survival value which they do not possess today, and so were maintained by natural selection at a certain level of excellence and efficiency.

The most difficult constituent of milk for an infant to digest is fat. If fat is not digested it may unite with alkali mineral elements in the alimentary tract, the products being carried out of the body in the chemical form of soaps, thus creating, in some cases, conditions of alkali deficiency and relative acidosis.

As we read the names of the many children in the families of our early American ancestors it is shocking to note the large percentage who died in infancy; but those pathetic sacrifices maintained the level of digestive competency on a higher plane than now prevails.

Similarly, the modern dairy industry has eliminated the survival value of the lactating function in womankind, and the capacity of the human mother to provide mineral as well as other nutriment to her infants has diminished. The cow helps us to "get by," and to hand on down nutritional problems of increasing difficulty.

That there has been an intensification of the severity of natural selection of human beings through a shift of emphasis from physical to certain mental and other nervous capacities, is indubitable. Thus the thousands of "jay-walkers" who awake, each year, in the land of the hereafter, must assist, willy-nilly, in the maintenance of our "sense of whereatness," but the net effect of the shift unquestionably leaves us with accentuated problems of mineral nutrition.

While, therefore, we need give no thought to the possibility of progressing backward to the nutritional situation of aboriginal man—living in natural harmony with his environment—we need at least to realize why we are where we are; which way we are progressing; and what it is practical to do about the nutritional disharmonies of the present.

CARIES.

Caries (1-5), or tooth decay of young people—an almost universal disorder of mineral metabolism among the civilized, and of immense importance in relation to arthritic, cardiac and renal disease—is at this time the subject of extensive investigation.

My view of this subject is merely that of the student of nutrition; but inasmuch as the dental pathologists are not in agreement, and have not solved the problem, we expect them to forgive us our unprofessional interest.

The most outstanding fact relating to caries is that it is primarily a disease of civilized mankind, in the sense that among many primitive peoples caries is remarkably less prevalent. Among possible contributory factors the following are considered by students of the subject, from various points of view:

1. Adhesive diets, especially such as contain much starch and sugar, yield acid, on fermentation, which destroy tooth enamel.
2. The impaction of carbohydrate foods, in situations leading to compression, contributes to fermentation effects.
3. In certain experimental work the size of food particles has seemed to be significant in relation to adhesion, impaction and fermentation.
4. Mucin plaques provide an environment favorable for decalcifying fermentation.
5. The quantities of calcium and phosphorus in the food, and the proportion of the quantity of the one to that of the other, as affecting the quantities and proportions of the same in the blood and the saliva, and especially as affecting the hydrogen-ion concentration and the acid-neutralizing capacity of the saliva, are believed by some to be significant.
6. Dietary deficiencies, in vitamins C, D and B, are said to be important in this relation; especially since deficiency of vitamin C may cause a separation of the odontoblastic layer from the dentine, and other associated abnormalities and degenerative changes; and since deficiency of vitamin D during the developmental period may cause the teeth, when erupted, to be defective in placement and structure.
7. Puberty and pregnancy are discussed as contributory causes.

8. Rickets, perhaps because of origin in part in the same conditions, is considered as predisposing to caries.

9. The presence of fluorine in foods or in drinking water is prejudicial to normality of dental structure.

But granting—for the sake of the argument—the validity of all these suggestions, I suspect that we have not yet mentioned the principal cause of caries, which appears, to my practical sense, to be disuse. The problem of caries, therefore, as I see it, is as to whether any combination of conditions as to nutrition and of environment will produce and will maintain normal tooth structure in the absence of the use to which teeth were adapted during the evolution of the species.

In this light, I doubt whether civilized mankind will ever have as good teeth as do some of the primitive peoples—unless we go back to diets which require vigorous chewing. When we chew by machinery we release the tension—physiologic and genetic as well—which, in a state of nature, maintains the teeth in a condition of normal excellence.

For the present, at least, therefore, I think that the practical question is as to the best compromise we can make with nature. To that end I would keep informed as to results of research in progress, and would attempt to prevent caries by dental treatment and dietary practice based especially upon the following:

1. The prevailing doctrine of the dental sanitarians—based upon the ideas of Miller, and those who have followed, and modified, and extended his conclusions as to the significance of the acid fermentation of carbohydrates;

2. The conclusions of Mrs. Mellanby as to the importance of vitamin D in relation to tooth development, in the prenatal as well as the postnatal stage;

3. The ideas of Bunting and associates, and many others, of the importance of a low-sugar diet, and an effective dental antiseptic.

4. The findings of Howe, as to the importance of vitamin C, and of Hanke and associates as to the efficacy of liberal use of citrous fruit juice;

5. The evidence, from many sources, as to adequate calcium and phosphorus contents of the diet; and, above all,

6. The observations of Waugh (6), and of others, on the teeth of primitive peoples, which seem to indicate the importance of vigorous use.

The Eskimos have the largest jaws and best teeth of any existing race, but after a single generation on the white man's diet, there is marked degeneration in the size and development of the jaws, and in the regularity and soundness of the teeth. Waugh concludes that "the American Eskimo is veritably paying for his civilization with his teeth."

MOTTLED ENAMEL.

Another abnormality of the teeth, the cause of which as a mineral disorder has only recently been discovered, is mottled enamel.

The enamel of the teeth becomes dull in appearance, chalky, pitted, structurally weak, lacking in cementing substance between the rods, and as a secondary effect may become variously stained.

Black and McKay (7), and H. V. Churchill (8) published early studies relating to this condition in the United States; but Margaret C. Smith (9), and associates, of the Arizona Agricultural Experiment Station, first clearly showed that the mottling of enamel is caused by fluorine in the drinking water, by producing the mottling by administering sodium fluoride.

Since this difficulty arises only from the use of drinking water from certain particular sources, the remedy is obvious.

ANEMIA.

Simple anemia is known to all as an iron-deficiency disease. The iron-poor foods of greatest importance in this relation are white flour, sugar and milk; and the foods of greatest importance because of their richness in iron are red meats and liver, green vegetables and eggs.

Anemia is common in infants (10)—whether naturally fed or bottle fed—and they respond readily to iron medication, which suggests that the aboriginal baby cut its teeth on a bone, and got some valuable shreds of meat at an early age.

The silly anti-meat propaganda of the recent years, seems about to have spent itself, and pediatric practice is swinging back toward the attitude of our parents and of our remote ancestors in the matter of meat for children.

Smythe and Miller (11) found that the percentage iron content of the body of the albino rat diminishes by a half during the suckling period, but rapidly increases to the normal

after solid food is taken, which throws light upon the situation of the human infant.

It is possible to get the supplementary iron required by infants from vegetable foods, and from drugs; but in my opinion beef juice, scraped beef and egg yolk are more natural sources of iron, and highly desirable dietary components on other accounts.

When I was a child our old-fashioned family doctor recommended steel saw filings, on bread and butter, for my sister's anemia; and the treatment was efficacious even beyond expectations, because my sister not only recovered from her anemia but became, and is today, a violinist—which testimonial for saw-filings should be noted by manufacturers of saws and files, as well as violins.

Miller and Forbes compared protein foods of many kinds as sources of iron, and found the meats to be the best and milk the poorest of those studied, in this respect.

Whipple and Mrs. Robscheit-Robbins (12) made an unusually extensive series of studies of the blood-building values of foods, with dogs as subjects. While it was clear that iron is important in this respect, it was equally clear that something else—found even in fruits—contributes to the ability of the dogs to synthesize hemoglobin.

Important later progress in this relation was the discovery of E. B. Hart and associates (13) that a trace of copper is effective as a supplement to iron for hemoglobin synthesis. Copper is contained in many, at least, but not in all foods.

Many vegetable foods contain approximately 2 parts of copper per 1000 of fresh substance—milk containing only one-third of this quantity—while some vegetables, and nuts, and cereals, contain several or many times this quantity. It is highest in the germs of seeds, which suggests its connection with the active metabolism of these parts (14).

Copper is not usually in deficient supply in otherwise practical diets, but may be so in particular cases.

Pernicious anemia is caused by an organic deficiency of the stomach, and is not within the field of this discussion of mineral metabolism.

THE IODINE PROBLEM.

One of the most important and clear-cut situations in the field of mineral nutrition is the relation of the iodine intake to the function of the thyroid, and to associated functions (15).

The thyroid gland regulates the rate at which the fundamental chemical reactions of the body are carried out, and is intimately related to the heat production.

Simple goiter is a hypertrophy of the thyroid, the first cause commonly being deficient intake of iodine.

Among the organs of the body, in addition to the thyroid, the hair, skin and nails are comparatively rich in iodine (16), and the condition of these parts is intimately related to the thyroid, and to iodine metabolism.

Seaweeds, burnt sponge, and preparations of the thyroid, which are exceedingly rich in iodine, had been used by the Chinese in the treatment of goiter for thousands of years before the discovery of iodine by Courtois in 1811.

In 1820 the chemist Dumas and the physician Coindet learned that iodine would cure some cases of goiter; but not until 1850 did Chatin advance the hypothesis that the deficiency of iodine in certain countries causes goiter; and two years later he determined that the iodine content of foods differs in accord with the iodine content of the soils on which they are grown. Recently it has been learned that the iodine content of milk and of eggs can be similarly modified, by iodine feeding of the animals which produce them.

In 1895 Baumann discovered iodine in the thyroid, and in 1914 Kendall isolated thyroxin, the active principle of the thyroid, containing 65 per cent of iodine.

Sea water contains iodine, as also do marine organisms. Deposits of salts formed by evaporation of sea water, therefore, contain iodine, but in the usual preparation of salt for nutritional or for technical use the iodine is lost. If the total iodine were retained there would be 2000 parts of iodine per billion of salt. It is much easier to restore iodine to refined salt than to retain it through the process of refinement.

The iodine content of drinking water varies enormously. McClendon and Williams, and McClendon and Hathaway found iodine in city water supplies to vary between 184.7 parts per billion in a deep well water from Mexia, Texas, and very small fractions of one part per billion in many cases. In the Scioto river water at Columbus, Ohio, they found 0.21 of one part per billion of iodine.

The iodine content of foods varies much in different parts of the United States, and the incidence of goiter likewise varies,

in general harmony with iodine deficiency of foods and drinking water.

Among the foods containing the highest quantities are oysters, clams, marine fish and Irish moss. Red cabbage is comparatively rich in iodine; whole potatoes and apples are much richer in iodine than are these foods after being peeled; and vegetables must lose a large part of their iodine into the water in which they are cooked; but immeasurably more important than the kind of food, in this relation, is the iodine content of the soil. Foodstuffs in general contain enough iodine, except as the soil on which they are grown is deficient.

In 1917 Marine and Kimball experimented in the schools of Akron, Ohio; 2190 school girls took 2 grams of sodium iodide twice a year for 3 years. Of these only 5 developed goiter, while of 2,305 girls not given iodine, and observed as controls, 495 developed goiter. The results of this experiment were so striking and convincing that iodine prophylaxis for goiter was taken up in many parts of the United States, New Zealand and India. The administration of iodine for the prevention of goiter is under government control in Switzerland and Italy.

Minimum effective iodine dosage has not been satisfactorily established. The use of iodine, and the quantity used, should be determined by a physician.

Eggenberger states that the biological minimum iodine intake to prevent goiter in human beings is 0.04 mg. per day—which would be a total of about 15 grams per year.

Hathaway advocates iodine surveys of all goitrous regions, the addition of sodium iodide to the water supplies of cities and towns, and the use of iodized table salt or tablets in rural communities.

The addition of sodium iodide to the city water supplies is practiced in several cities in this country, but it is cheaper for the people to use iodized salt, if they will do it, since only a small part of a city water supply is used for drinking.

O. P. Kimball (17) says that every iodine survey emphasizes the importance of goiter prevention during pregnancy. "We cannot stress this point too strongly and in endemic goiter districts we need the attention of the physicians who educate and direct women through this important period, and of every prospective mother. It is during pregnancy that the general

use of iodized salt will be of greatest value and should be used in every case unless otherwise directed by a physician."

"The history of this problem for the past century teaches most emphatically that the treatment of goiter is very unsatisfactory and accomplishes very little toward the control of the disease, but those attacking the problem from the viewpoint of preventive medicine—physiologists, biochemists and public health authorities—have accumulated sufficient evidence to justify the assertion that endemic goiter is the easiest known disease to prevent."

RICKETS.

Numerous surveys of infant nutrition have shown that affliction with a slight degree of rickets is exceedingly common throughout the temperate zone (18), and that a large part of these cases recover, as abundant sunshine and mixed diet replace the indoor confinement and the milk diet of early infancy, without this condition being recognized. In fact, the human infant seems to live close to the border line of rickets, because woman's milk and cow's milk as well contain, at the most, only a narrow margin of excess vitamin D, which is essential to the most efficient utilization of calcium and phosphorus.

Aside from the factors mentioned, refined cereal foods are most largely responsible for the existence of this disease, as they crowd out of the diet other foods containing more of the bone-growing requisites.

Man is one of the slowest-growing of all animals; he is adapted to and is provided with a comparatively low-calcium diet; and he is not capable of tolerating much interference with the utilization of his mineral nutrients. These facts imply that during the development of the species the conditions preventive of rickets—among which is sunshine—were dependably present in requisite quantities.

In spite of the much higher calcium and phosphorus content of cow's milk than of woman's milk the infant fed on cow's milk is much more prone to rickets than is the infant which receives its mother's milk—the calcium and phosphorus of cow's milk being not so well utilized.

The utilization of the calcium and phosphorus of milk by an infant, and therefore its tendency to develop rickets, is affected by many conditions, as to food supply and preparation, environment, digestive capacity, and rate of growth (19-24).

Some of these conditions are:

1. The quantities of calcium and phosphorus present in the diet.
2. The ratio of calcium to phosphorus in the diet.
3. The vitamin D content of the milk, and other constituents of the diet.
4. The exposure of the infant to solar radiation.
5. Rapidity of growth—which, if extreme, may contribute to the production of rickets.
6. Vigor of digestion—especially capacity to digest milk fat, which if not digested interferes with the utilization of calcium and phosphorus.
7. The time of year—as determining the intensity of the sunshine, and the vitamin values of foods.

The usual causes of rickets are combinations of unfavorable conditions as to these factors. It is normally curable by removal of the causes, and the provision of conditions sufficiently favorable for the nutrition of the bones.

Artificially fed infants, and many naturally fed infants as well, need supplementary vitamin D. It becomes a practical question, then, as to how this nutrient shall be provided—which may be in cod-liver oil, in other such oils, in concentrates prepared from such oils, in irradiated ergosterol, or in irradiated foods containing ergosterol—or it may be formed, in the skin, by exposure to sunshine or to special ultra-violet irradiation.

Irradiation by direct sunshine, or by mercury vapor or carbon arc lamps, is much more effective than is dependence on the penetration of special window glass by ultra-violet rays of sunlight.

Very many foods can be enriched in vitamin D by irradiation, and, so enriched, they are endowed with potency to heal rickets.

Milk can be enriched in vitamin D by feeding irradiated foods or drugs to the cow; but this is not a quantitatively efficient process—direct irradiation being much the most effective method of accomplishing the purpose.

The University of Wisconsin Alumni Research Foundation recently announced the perfection of an apparatus for the commercial irradiation of milk. The device consists of an upright cylinder down the inner walls of which the milk flows in a thin sheet, being exposed, during the process, to irradiation from a 12,000-watt battery of electric lamps which emit ultra-

violet light, the milk acquiring vitamin D potency about equal to that of good cod-liver oil.

It is possible to take too much vitamin D (25), with the result that calcium may be deposited in the blood vessels, heart, stomach, lungs, kidneys and muscles, and that there is an excess of calcium in the blood as well. Responsible guidance in this relation, therefore is necessary.

The prevention of rickets should begin with the care and feeding of the expectant mother (26). Her diet will affect the vitamin D content of her milk.

Among the foods deserving of mention as contributing to the rickets-preventive capacities of the child's diet, milk deserves first mention, because it is rich in calcium and phosphorus, but by itself cannot be regarded as a rickets-preventive, because it is not rich in vitamin D. Egg yolk is rich in vitamin D; butter is a fair source of D; while cod liver and other fish liver oils are very rich in this nutrient.

THE MINERAL NUTRITION OF LIVESTOCK.

The mineral nutrient problems of domesticated animals may be classified as of geographical or of physiological origin.

The deficiencies of geographical origin—which are dependent on soil and forage composition—have to do with phosphorus, iron and iodine especially, but also with calcium, and affect the different kinds of animals in accord with the proportion of forage in their respective rations, and with the magnitude of the demands for mineral nutriment which are made upon them by their different lives and functions.

HORSES.

The problems of mineral nutrition of horses depend primarily upon the facts that in their use the bones and tendons are put to such strain as to cause the many bone unsoundnesses with which all horsemen are unhappily familiar.

These unsoundnesses are ordinarily the results of maltreatment rather than malnutrition.

Under conditions of ordinarily good farm management there are no commonly obvious faults of mineral nutrition of horses. It is true that under conditions of extreme mineral nutrient deficiency horses manifest symptoms of osteoporosis, rickets, anemia and goiter, similar to those of other animals, but these conditions are comparatively rare.

Horses do not crave mineral feeds other than common salt; they are usually repelled by bone preparations, though they will sometimes take a refined steamed bone meal; but they will take and are sometimes given rock phosphate preparations—which, however, should not be fed to any animal—because of their fluorine content.

Owners of horses commonly depend on good quality of natural foods, to supply the needed mineral nutrients, and this is usually sufficient.

CATTLE.

Special concern as to the mineral nutrition of cattle (27) depends on the several-fold increase in milk production which has been accomplished by selective breeding. Cattle are rapid growing animals, and their milk is correspondingly rich in mineral nutrients. The cow, therefore, must have the supplies needed to carry on an extensive business in these substances.

The geographic mineral problem, with cattle, has to do especially with the phosphorus content of roughage, depending on the fact that there are areas of phosphorus deficient soil in many parts of the world, including several regions in the United States, but constituting a small part of the whole agricultural area.

The results of phosphorus deficiency of forage for cattle are a complication of disorders dependent upon malnutrition of the bones, depraved appetite, and generally deranged metabolism.

The administration of calcium carbonate accentuates these troubles, and the feeding of bone meal, and other phosphate foods, relieves them.

The problem of calcium content of roughage for cattle is a minor one, though there is some evidence that cattle receiving only low-calcium prairie hay for roughage may be benefited by the feeding of pulverized limestone (28).

Cattle suffer from iron deficiency in comparatively few regions, such as certain parts of Florida (29), in which the roughage is abnormally poor in iron, or in iron and copper together. The obvious method of relief is effective.

Calves do not suffer from iron deficiency, as do some other suckling animals, because they begin to eat a little hay when only a few days old—and the hay contains the needed iron.

Cattle suffer from iodine deficiency—as also do horses, sheep, and swine—in regions of low-iodine soils, foodstuffs and drinking water. This trouble appears mainly in intra-uterine development. The result, in cattle, sheep and horses, is goiter, and, in swine, also hairlessness. Iodine deficiency is easily preventable by the use of iodized salt.

Cattle may suffer from fluorine poisoning—which affects calcium metabolism, especially of the teeth (30)—but this fact seems to be practically significant at this time only in relation to the use of rock phosphate as a mineral feed.

Prominent features of the physiological mineral problem of cattle are the following:

In its practical aspects this problem relates only to the dairy cow (31–35).

It is normal for a dairy cow to be in negative calcium and phosphorus balance early in the period of lactation; later, when the mineral demands of milk production have naturally diminished, storage comes to prevail.

The annual cycle of lactation and gestation constitute the significant unit, in point of time, in this relation.

From this point of view—with ordinarily abundant milk secretion—as in average, successful production, special mineral feeds are not needed if the cow receives roughage of normal composition, in normal quantity.

Limestone and bone meal may perhaps be needed during unusually heavy milk production, or if the roughage given is restricted in quantity, or is poor in phosphorus or in calcium; but evidence as to the exact conditions which may justify the use of such feeds for dairy cows has not been established.

SHEEP.

The selective improvement of sheep has greatly increased the growth of wool by this species; and it is natural to mention sulphur metabolism in this relation, because of the high sulphur content of wool, though there is comparatively little to be said of mineral sulphur metabolism, in spite of the almost limitless ground for interest in the metabolism of organic sulphur compounds.

The nutrition of sheep doubtless requires a larger proportion of sulphur in the ration than is needed by any other animal, and it is probably more than an accident that a considerable group of brassicaceous plants, and legumes, which are rich in

sulphur, have established themselves, through the ages, as mainstays of sheep husbandry.

Sulphate and elemental sulphur have long been considered without value in the synthesis of the sulphur compounds of animal tissues, but in this relation one must not be needlessly dogmatic, because bacteria and yeasts in the alimentary tract can utilize inorganic sulphur, and the animal can digest and utilize these organisms.

Sulphur occurs in plants in many conditions and compounds—organic and inorganic—but in animals mainly as cystine, which is beta-thio-alpha-amino propionic acid, and also as methionine, which is alpha-amino gamma-methylthiol butyric acid.

According to A. T. King (36) the conversion of non-cystine sulphur into cystine, in the alimentary tract of the sheep, may depend upon bacteria which may be stimulated by iron salts in the ration, or by the sheep eating earth which is rich in iron.

Sheep suffer from forage deficiencies in calcium, phosphorus and iron—dependent on soil conditions—as do other farm animals, and likewise are benefited by the feeding of these elements in suitable inorganic compounds; but the occasions for giving mineral feeds to sheep are rare in this country—though frequent in some others.

On the borderline between organic and inorganic sulphur metabolism is the recent work, of unusual interest, by Hammett (37) and associates, which they interpret as a demonstration of the control of cell division by the naturally occurring equilibrium comprised of sulfhydryl and its partially oxidized derivatives, to which I can only allude, in passing.

SWINE.

In the mineral nutrition of swine there is no problem of soil and forage mineral deficiency, as with horses, cattle and sheep, because swine eat comparatively little roughage; but their mineral nutrition is much more likely to constitute a critical problem for this same reason—that they do eat comparatively little roughage—which is usually rich in mineral nutrients.

Other reasons for the critical situation of swine with reference to mineral nutrition are that they are raised mostly in rather close confinement, and therefore have little opportunity to gather mineral nutrients for themselves; that it is customary to

raise swine largely on low-calcium cereal feeds; and that swine develop with extreme rapidity—therefore requiring rations rich in mineral nutrients. Also they have been developed, from time to time, into physical types placing special demands upon the skeleton. In any case the heavy load of flesh which swine carry calls for strength of bones; but the refinement of skeleton which has at times been popular demands unusually dense quality of bone; at the other extreme, the so-called “big type” in the Poland China breed demanded the production of large size of bone at a rate in some cases exceeding the capacity of swine to produce normally dense bone. Also the extreme length and level back which were once popular in the Berkshire breed were found impracticable, because they placed upon the skeleton and tendons demands which they could not meet.

It is said that men will never understand the philosophy of women's hats; but men have produced some styles in pigs which suggest that men's and women's mental processes are not wholly dissimilar.

Malnutrition of the bones of swine is, under some conditions, osteoporosis—simple mineral starvation; but, under other conditions, the disorder is rickets.

The cause and the prevention of swine rickets have to do mainly with the levels of calcium and phosphorus, the proportion of calcium to phosphorus, and the vitamin D content of the ration.

The best sources of mineral nutriment for swine are leguminous roughage, skim milk, tankage, bone meal and pulverized limestone.

In addition to the skeletal problem in swine there is also, strange to say, an important problem of anemia in suckling pigs which are reared indoors, as in the winter, without contact with earth. This disorder, the nature of which was discovered by McGowan and Crichton (38) of Rowett Institute, is readily preventable by administration of iron salts, or by giving the pigs chunks of sod to chew.

POULTRY.

The following observations relating to the mineral nutrition of poultry were adapted from a statement provided by the kindly cooperation of Dr. J. E. Hunter, of the Pennsylvania Agricultural Experiment Station.

In the mineral nutrition of chickens there are two situations of special interest—rickets, and “hock disease.”

Rickets, in poultry, is caused by conditions similar to those which bring about this disease in other animals, though in this relation the students of the subject have not yet reached complete agreement.

Hock disease is distinctly different from rickets. It is related to excess rather than to deficiency of mineral nutrients. Other conditions remaining the same, the percentage incidence of hock disease may be experimentally regulated in converse agreement with the bone meal content of the ration; for instance, with 2 percent of bone meal there may be an approximately 50 percent incidence, and with 4 percent bone meal a 95 percent incidence is typical.

In hock disease the tibial-metatarsal joint becomes swollen; the articular cartilage of the tibia departs slightly from its normal position; the principal tendons in this joint slip from their condyles, and the bird is permanently disabled.

Strange to say, oat hulls, or rice bran, in proper proportion in the ration, prevent hock disease in the presence of conditions which otherwise cause it; and Hunter states that he has shown that this beneficial effect cannot be attributed to the fibrous content of the supplement, or to the lowered rate of growth induced by the feeding of fibrous components. The nature of the protective substance in oat hulls and rice bran remains an interesting problem.

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Inventions and Inventors.

This volume is intended as a guide-book for those whose activities include inventive or creative procedures. Mechanical invention, chemical and electrical invention, and even psychological and biological invention are discussed. As might be surmised, the latter two discussions are highly speculative in nature. The general chapters on invention, inventors, patents, and the financing of such undertakings will be of interest to anyone with new ideas and the urge to exploit them.—L. H. S.

The Inventor and his World, by H. Stafford Hatfield. v + 269 pp. New York, E. P. Dutton and Co., 1933. \$2.40.